PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: JOHN P. PRATT
KILPATRICK STOCKTON LLP
1100 PEACHTREE STREET
SUITE 2800
ATLANTA, GA, 30309-4530

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 204409PCT	Date of Mailing *(day/month/year)* 04 JAN 2002 **FOR FURTHER ACTION** **See paragraphs 1 and 4 below**
International application No. PCT/US01/10525	International filing date *(day/month/year)* 30 MARCH 2001
Applicant IMAX CORPORATION	

1. [X] The applicant is hereby notified that the international search report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the international search report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in rules 90 *bis* 1 and 90 *bis* 3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer WILLIAM C. DOWLING Deborah Perry-Leeper Paralegal Specialist Technology Center 2800
Facsimile No. (703) 305-3230	Telephone No. (703) 308-1287

Form PCT/ISA/220 (July 1998)★

(See notes on accompanying sheet)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 204409PCT	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/US01/10525	International filing date *(day/month/year)* 30 MARCH 2001	(Earliest) Priority Date *(day/month/year)* 31 MARCH 2000
Applicant IMAX CORPORATION		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.
   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).
   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing:
   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readable form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.
2. [ ] **Certain claims were found unsearchable** (See Box I).
3. [ ] **Unity of invention is lacking** (See Box II).
4. With regard to the **title,**
   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:
5. With regard to the **abstract,**
   [ ] the text is approved as submitted by the applicant.
   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. The figure of the **drawings** to be published with the abstract is Figure No: 2
   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.
   [ ] None of the figures.

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

The technical features mentioned in the abstract do not include a reference sign between parentheses (PCT Rule 8.1(d)).

NEW ABSTRACT

An apparatus and technique for enhancing characteristics of electronic projection systems. Techniques may include both superimposition of sub-images and tiling of superimposed images, the combination which can be advantageous in improving resolution of projected images. the apparatus may include first and second SLM sets (1, 2) for forming the sub-images and a pyramid prism (10) for enacting the tiling of images. Pre-modulators and polarizing beam splitters (6, 7, 8) also may be used as parts of the system.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/10525

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G03B 21/14
US CL : 353/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : G03B 21/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,300,966 A (UEHIRA ET AL.) 05 APRIL 1994 (05.04.94) SEE ENTIRE DOCUMENT	1, 3, 15
A	US 6,017,123 A (BLEHA ET AL.) 25 JANUARY 2000 (25.01.00) SEE ENTIRE DOCUMENT	1-16
A	US 5,626,411 A (TAKAHASHI ET AL.) 06 MAY 1997 (06.05.97) SEE ENTIRE DOCUMENT	1-16

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 17 DECEMBER 2001	Date of mailing of the international search report 04 JAN 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer WILLIAM C. DOWLING Telephone No. (703) 308-1287

Deborah Perry-Leeper
Paralegal Specialist
Technology Center 2800

Form PCT/ISA/210 (second sheet) (July 1998)★

09/980068

PCT REQUEST

204409PCT

Original (for SUBMISSION) - printed on 30.03.2001 09:53:58 AM

0	For receiving Office use only	
0-1	International Application No.	PCT/US 01/10525
0-2	International Filing Date	(30.03.01) 30 MAR 2001
0-3	Name of receiving Office and "PCT International Application"	PCT INTERNATIONAL APPLICATION RO/US

0-4	Form - PCT/RO/101 PCT Request	
0-4-1	Prepared using	PCT-EASY Version 2.91 (updated 01.01.2001)
0-5	Petition The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	Receiving Office (specified by the applicant)	United States Patent and Trademark Office (USPTO) (RO/US)
0-7	Applicant's or agent's file reference	204409PCT
I	Title of invention	DIGITAL PROJECTION EQUIPMENT AND TECHNIQUES
II	Applicant	
II-1	This person is:	applicant only
II-2	Applicant for	all designated States except US
II-4	Name	IMAX CORPORATION
II-5	Address:	2525 Speakman Drive Mississauga, Ontario L5K 1B1 Canada
II-6	State of nationality	CA
II-7	State of residence	CA
II-8	Telephone No.	(905) 403-6500
II-9	Facsimile No.	(905) 403-6468
III-1	Applicant and/or inventor	
III-1-1	This person is:	applicant and inventor
III-1-2	Applicant for	US only
III-1-4	Name (LAST, First)	GIBBON, Michael
III-1-5	Address:	1340 Monk's Passage Oakville, Ontario L6M 1J5 Canada
III-1-6	State of nationality	CA
III-1-7	State of residence	CA

PCT REQUEST

204409PCT

Original (for **SUBMISSION**) - printed on 30.03.2001 09:53:58 AM

III-2	Applicant and/or inventor	
III-2-1	This person is:	applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	ZHOU, Samuel, Z.
III-2-5	Address:	50 Willesden Road North York, Ontario M2H 1V5 Canada
III-2-6	State of nationality	CA
III-2-7	State of residence	CA
III-3	Applicant and/or inventor	
III-3-1	This person is:	applicant and inventor
III-3-2	Applicant for	US only
III-3-4	Name (LAST, First)	ADKINS, Sean
III-3-5	Address:	107 1235 Nelson Street Vancouver, British Columbia V5T 1C5 Canada
III-3-6	State of nationality	US
III-3-7	State of residence	CA
III-4	Applicant and/or inventor	
III-4-1	This person is:	applicant and inventor
III-4-2	Applicant for	US only
III-4-4	Name (LAST, First)	ANIKITCHEV, Sergei, G.
III-4-5	Address:	2204-3980 Carrigan Court Burnaby, British Columbia V3N 3S6 Canada
III-4-6	State of nationality	CA
III-4-7	State of residence	CA
III-5	Applicant and/or inventor	
III-5-1	This person is:	applicant and inventor
III-5-2	Applicant for	US only
III-5-4	Name (LAST, First)	READ, Steven
III-5-5	Address:	3961 Refrew Cres. Mississauga, Ontario L5L 4J6 Canada
III-5-6	State of nationality	CA
III-5-7	State of residence	CA
III-6	Applicant and/or inventor	
III-6-1	This person is:	applicant and inventor
III-6-2	Applicant for	US only
III-6-4	Name (LAST, First)	MOSS, Graham, H.
III-6-5	Address:	12 Aspenwood Drive Oldham, Lancashire OL9 9UP United Kingdom
III-6-6	State of nationality	GB
III-6-7	State of residence	GB

PCT REQUEST

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Original (for SUBMISSION) - printed on 30.03.2001 09:53:58 AM

III-7	**Applicant and/or inventor**	
III-7-1	This person is:	applicant and inventor
III-7-2	Applicant for	US only
III-7-4	Name (LAST, First)	QUINN, Dermot, J.
III-7-5	Address:	38 Inglewood Avenue Birkby Huddersfield, Yorkshire HD2 2DS United Kingdom
III-7-6	State of nationality	GB
III-7-7	State of residence	GB
III-8	**Applicant and/or inventor**	
III-8-1	This person is:	applicant and inventor
III-8-2	Applicant for	US only
III-8-4	Name (LAST, First)	WILDING, Steven
III-8-5	Address:	235 Rochdale Old Road Fairfield Bury, Lancashire BL9 7SA United Kingdom
III-8-6	State of nationality	GB
III-8-7	State of residence	GB
III-9	**Applicant and/or inventor**	
III-9-1	This person is:	applicant and inventor
III-9-2	Applicant for	US only
III-9-4	Name (LAST, First)	ECKERSLEY, Brian
III-9-5	Address:	46 Douglas Road Worsley Manchester, Lancashire M28 2SG United Kingdom
III-9-6	State of nationality	GB
III-9-7	State of residence	GB
IV-1	**Agent or common representative; or address for correspondence** The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
IV-1-1	Name (LAST, First)	PRATT, John, P.
IV-1-2	Address:	KILPATRICK STOCKTON LLP 1100 Peachtree Street Suite 2800 Atlanta, GA 30309-4530 United States of America
IV-1-3	Telephone No.	(404) 815-6500
IV-1-4	Facsimile No.	(404) 815-6555
IV-1-5	e-mail	DRussell@kilpatrickstockton.com

PCT REQUEST

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IV-2	Additional agent(s)	additional agent(s) with same address as first named agent
IV-2-1	Name(s)	EWING, IV, James, L.; RUSSELL, Dean, W.; GRAY, Bruce, D.; STOCKWELL, Mitchell, G.; TOCUPS, Nora, M.; SUTCLIFFE, Geoff, L.; MUSICK, Eleanor, M.; TURTON, Michael, J.; WILLIAMS, Camilla, C.; JOHNSON, Kristin, L.; GLOBERMAN, Kyle, M.; DIXON, Michael, K.; GAVIN, Geoffrey, K.; GORMAN, Heather, D.; HOLMES, Brenda, O.; KADABA, Vaibhav, P.; MALLATT, Kristin, M.; WANG, Li; CHAN, Christopher, J.; BRISKI, John, M.
V	**Designation of States**	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	EP: AT BE CH&LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE TR and any other State which is a Contracting State of the European Patent Convention and of the PCT
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	CA JP US
V-5	**Precautionary Designation Statement** In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.	
V-6	**Exclusion(s) from precautionary designations**	NONE
VI-1	**Priority claim of earlier national application**	
VI-1-1	Filing date	31 March 2000 (31.03.2000)
VI-1-2	Number	0007891.5
VI-1-3	Country	GB
VI-2	**Priority claim of earlier national application**	
VI-2-1	Filing date	03 July 2000 (03.07.2000)
VI-2-2	Number	60/215,715
VI-2-3	Country	US
VI-3	Priority document request The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	VI-2

PCT REQUEST

204409PCT

Original (for SUBMISSION) - printed on 30.03.2001 09:53:58 AM

VII-1	International Searching Authority Chosen	United States Patent and Trademark Office (USPTO) (ISA/US)	
VIII	Check list	number of sheets	electronic file(s) attached
VIII-1	Request	5	-
VIII-2	Description	9	-
VIII-3	Claims	3	-
VIII-4	Abstract	1	EZABST00.TXT
VIII-5	Drawings	4	-
VIII-7	TOTAL	22	
	Accompanying items	paper document(s) attached	electronic file(s) attached
VIII-8	Fee calculation sheet	✓	-
VIII-16	PCT-EASY diskette	-	diskette
VIII-17	Other (specified):	PCT Transmittal Letter (Express Mail Label No. EL572469905US)	-
VIII-18	Figure of the drawings which should accompany the abstract	2	
VIII-19	Language of filing of the international application	English	
IX-1	Signature of applicant or agent	Dean W Russell	
IX-1-1	Name (LAST, First)	RUSSELL, Dean, W.	

FOR RECEIVING OFFICE USE ONLY

10-1	Date of actual receipt of the purported international application	JC07 Rec'd PCT/PTO 30 MAR 2001 (30.03.01)
10-2	Drawings:	
10-2-1	Received	
10-2-2	Not received	
10-3	Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application	
10-4	Date of timely receipt of the required corrections under PCT Article 11(2)	
10-5	International Searching Authority	ISA/US
10-6	Transmittal of search copy delayed until search fee is paid	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	Date of receipt of the record copy by the International Bureau	

PCT (ANNEX - FEE CALCULATION SHEET)

204409PCT

Original (for SUBMISSION) - printed on 30.03.2001 09:53:58 AM

(This sheet is not part of and does not count as a sheet of the international application)

0	**For receiving Office use only**			
0-1	International Application No.	PCT/US 01/10525		
0-2	Date stamp of the receiving Office	(30.03.01)	30 MAR 2001	
0-4	**Form - PCT/RO/101 (Annex) PCT Fee Calculation Sheet**			
0-4-1	Prepared using	PCT-EASY Version 2.91 (updated 01.01.2001)		
0-9	**Applicant's or agent's file reference**	204409PCT		
2	**Applicant**	IMAX CORPORATION, et al.		
12	**Calculation of prescribed fees**	fee amount/multiplier	total amounts (USD)	
12-1	Transmittal fee T	⇨	240	240
12-2	Search fee S	⇨	700	700
12-3	International fee Basic fee (first 30 sheets) b1	382		265
12-4	Remaining sheets	0		
12-5	Additional amount (X)	9		
12-6	Total additional amount b2	0		
12-7	b1 + b2 = B	382		265
12-8	Designation fees Number of designations contained in international application	4		
12-9	Number of designation fees payable (maximum 6)	4		
12-10	Amount of designation fee (X)	82		
12-11	Total designation fees D	328		328
12-12	PCT-EASY fee reduction R	-117		
12-13	Total International fee (B+D-R) I	⇨	593	593
12-14	Fee for priority document Number of priority documents requested	1		
12-15	Fee per document (X)	15		
12-16	Total priority document fee P	⇨	15	15
12-17	TOTAL FEES PAYABLE (T+S+I+P)	⇨	1,548	1548
12-19	**Mode of payment**	cheque		
12-20	**Deposit account instructions** The receiving Office:	United States Patent and Trademark Office (USPTO) (RO/US)		
12-20-2	is hereby authorized to charge any deficiency or credit any over-payment in the total fees indicated above to my deposit account	✓		
12-21	Deposit account No.	11-0855		
12-22	Date	30 March 2001 (30.03.2001)		

PCT (ANNEX - FEE CALCULATION SHEET) 204409PCT

Original (for SUBMISSION) - printed on 30.03.2001 09:53:58 AM

12-23	Name and signature	RUSSELL, Dean, W.

VALIDATION LOG AND REMARKS

13-2-2	Validation messages States	Green? More designations could be made. The following States have not been designated: AP:(GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW); EA:(AM, AZ, BY, KG, KZ, MD, RU, TJ, TM); OA:(BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG); AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CH, LI, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW. Please verify.
13-2-6	Validation messages Contents	Yellow! The power of attorney or a copy of the general power of attorney will need to be furnished unless all applicants sign the request form.
		Green? Priority 1. The priority document is not enclosed. (The applicant must furnish it within 16 months from the earliest priority date claimed)

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 December 2001 (20.12.2001)

PCT

(10) International Publication Number
WO 01/96907 A3

(51) International Patent Classification[7]: G03B 21/14

(21) International Application Number: PCT/US01/10525

(22) International Filing Date: 30 March 2001 (30.03.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0007891.5 31 March 2000 (31.03.2000) GB
60/215,715 3 July 2000 (03.07.2000) US

(71) Applicant *(for all designated States except US)*: **IMAX CORPORATION** [CA/CA]; 2525 Speakman Drive, Mississauga, Ontario L5K 1B1 (CA).

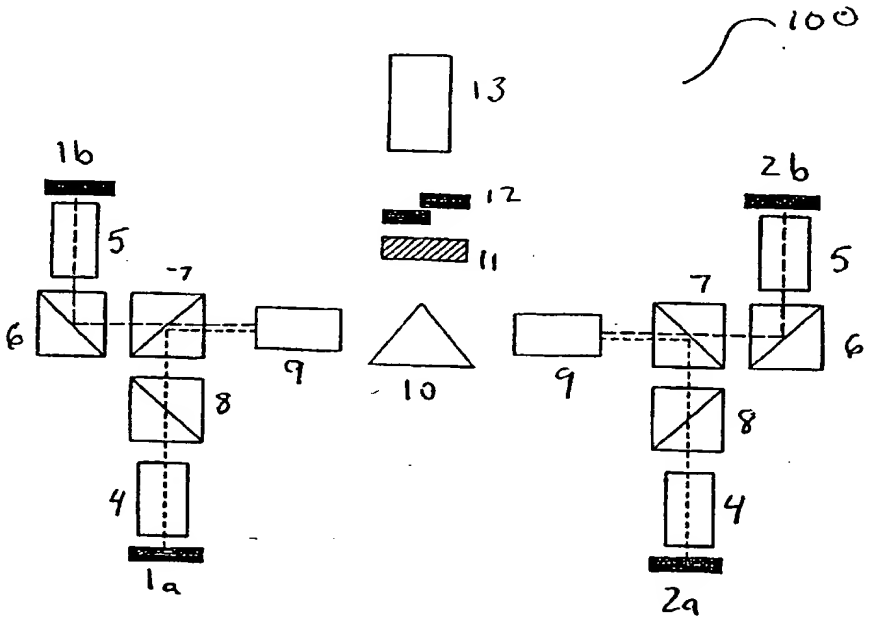
(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **GIBBON, Michael** [CA/CA]; 1340 Monk's Passage, Oakville, Ontario L6M 1J5 (CA). **ZHOU, Samuel, Z.** [CA/CA]; 59 Willesden Road, North York, Ontario M2H 1V5 (CA). **ADKINS, Sean** [US/CA]; 107 1235 Nelson Street, Vancouver, British Columbia V5T 1C5 (CA). **ANIKITCHEV, Sergei, G.** [CA/CA]; 2204-3980 Carrigan Court, Burnaby, British Columbia V3N 3S6 (CA). **READ, Steven** [CA/CA]; 3961 Renfrew Crescent, Mississauga, Ontario L5L 4J6 (CA). **MOSS, Graham, H.** [GB/GB]; 12 Aspenwood Drive, Oldham, Lancashire OL9 9UP (GB). **QUINN, Dermot, J.** [GB/GB]; 38 Inglewood Avenue, Birkby, Huddersfield, Yorkshire HD2 2DS (GB). **WILDING, Steven** [GB/GB]; 235 Rochdale Old Road, Fairfeld, Bury, Lancashire BL9 7SA (GB). **ECKERSLEY, Brian** [GB/GB]; 46 Douglas Road, Manchester, Lancashire M28 2SG (GB).

(74) Agents: **PRATT, John, P.** et al.; Kilpatrick Stockton LLP, 1100 Peachtree Street, Suite 2800, Atlanta, GA 30309-4530 (US).

(81) Designated States *(national)*: CA, JP, US.

[Continued on next page]

(54) Title: DIGITAL PROJECTION EQUIPMENT AND TECHNIQUES



(57) Abstract: An apparatus and technique for enhancing characteristics of electronic projection systems. Techniques may include both superimposition of sub-images and tiling of superimposed images, the combination of which can be advantageous in improving resolution of projected images. The apparatus may include first and second SLA sets (1, 2) for forming the sub-images and a pyramid prism (10) for enacting the tiling of images. Pre-modulators and polarizing beam splitters (6, 7, 8) also may be used as parts of the system.

WO 01/96907 A3

(84) **Designated States** *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— *with international search report*

(88) **Date of publication of the international search report:**
4 April 2002

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/10525

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G03B 21/14
US CL : 353/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : G03B 21/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,300,966 A (UEHIRA ET AL.) 05 APRIL 1994 (05.04.94) SEE ENTIRE DOCUMENT	1, 3, 15
A	US 6,017,123 A (BLEIA ET AL.) 25 JANUARY 2000 (25.01.00) SEE ENTIRE DOCUMENT	1-16
A	US 5,626,411 A (TAKAHASHI ET AL.) 06 MAY 1997 (06.05.97) SEE ENTIRE DOCUMENT	1-16

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 DECEMBER 2001	04 JAN 2002

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Form PCT/ISA/210 (second sheet) (July 1998)*

Technology Center 2800

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 December 2001 (20.12.2001)

PCT

(10) International Publication Number
WO 01/96907 A2

(51) International Patent Classification[7]: G02B

(21) International Application Number: PCT/US01/10525

(22) International Filing Date: 30 March 2001 (30.03.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0007891.5 31 March 2000 (31.03.2000) GB
60/215,715 3 July 2000 (03.07.2000) US

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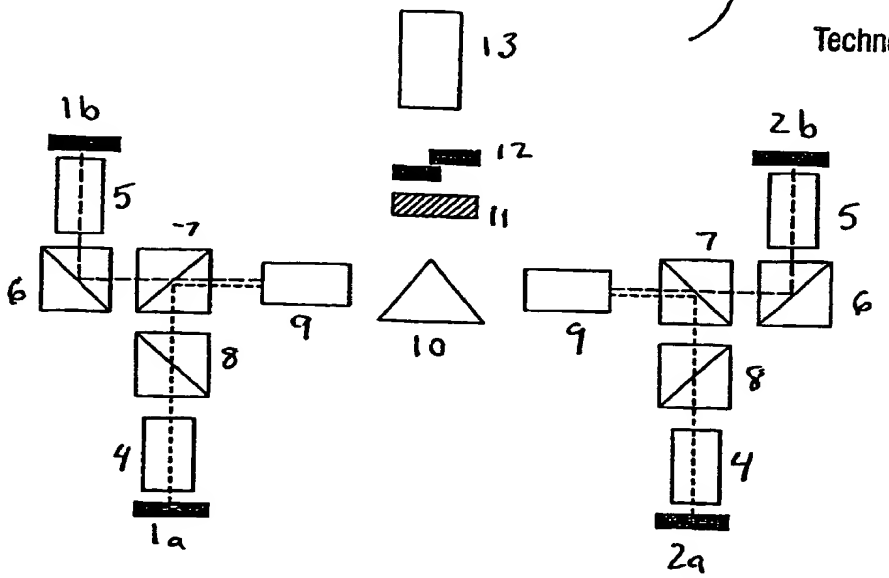
(81) Designated States *(national)*: CA, JP, US.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

[Continued on next page]

(54) Title: DIGITAL PROJECTION EQUIPMENT AND TECHNIQUES



(57) Abstract: Apparatus and techniques for enhancing characteristics of electronic projection systems are detailed. Included among the techniques are both superimposition of sub-images and tiling of superimposed images, the combination of which can be advantageous in improving resolution of projecting images. Pre-modulators and polarizing beam splitters also may be used as parts of the innovative systems.

WO 01/96907 A2

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DIGITAL PROJECTION EQUIPMENT AND TECHNIQUES

REFERENCE TO PROVISIONAL APPLICATION

This application is based on and hereby refers to U.S. Provisional Patent Application Serial No. 60/215,715, filed July 3, 2000, having the same title as appears above.

FIELD OF THE INVENTION

This invention relates generally to projection of images and more specifically to techniques and equipment for enhancing characteristics (including but not limited to dynamic range) of images projected electronically through, typically, digital projectors.

BACKGROUND OF THE INVENTION

U.S. Patent No. 5,386,253 to Fielding, incorporated herein in its entirety by this reference, discusses exemplary projection systems utilizing one or more spatial light modulators (SLMs). As noted in the Fielding patent:

> Spatial light modulator devices include so-called "active matrix" devices, comprising an array of light modulating elements, or "light valves," each of which is controllable by a control signal (usually an electrical signal) to controllably reflect or transmit light in accordance with the control signal. A liquid crystal array is one example of an active matrix device; another example is the deformable mirror device (DMD) developed by Texas Instruments . . . .

See Fielding, col. 1, ll. 13-21. Of course, yet other types of light "engines," or sources, exist, and various of them may be used in connection with the inventions described herein.

Regardless of the type of light sources and modulators used, audiences frequently desire to see images high in detail and richness and low in objectionable artifacts. High resolution and image quality in particular facilitates suspension of disbelief of an audience as to the reality of the projected images. Such quality indeed often is an important factor in the overall success of the motion picture viewing experience among today's audiences.

Producing these high-resolution images is not without added cost, however. Imax Corporation, for example, the intended assignee of this application, utilizes not only specialized cameras and projectors, but also seventy millimeter, fifteen perforation film to increase the resolution and quality of projected images. Conventional electronic projectors (and especially those utilizing SLMs), by contrast, generally cannot supply equivalent

resolution in projected images. As well, such electronic projectors frequently fail to furnish the dynamic range and overall brightness of images provided by large-format films. They nonetheless may desirably (or necessarily) be employed to display non-film-based images such as (but not limited to) computer-generated graphics or material captured with electronic cameras.

U.S. Patent No. 5,490,009 to Venkateswar, et al., also incorporated herein in its entirety by this reference, details techniques purporting to enhance image resolution in systems employing multiple SLMs. According to the Venkateswar patent, sub-images generated by different SLMs are simultaneously displayed such that some sub-images are spatially offset horizontally or vertically from others. This results in partial superposition of the sub-images, with the offset supposedly allowing a two-SLM system (with each SLM having "x" pixels per row) to provide "a perceived quality approaching that of a system that generates a single image from an SLM having 2(x) pixels per row." See Venkateswar, col. 2, ll. 41-43.

U.S. Patent No. 5,612,753 to Poradish, et al., additionally incorporated herein in its entirety by this reference, discloses alternative techniques for, purportedly, increasing brightness of projected images or extending the projected number of gray levels. Figure 1 of the Poradish patent illustrates a projection system in which light from two sources is reflected toward separate lens systems and then focused separately on distinct color wheels. Light from each color wheel thereafter is reflected to an SLM (preferably a DMD) via a total internal reflection (TIR) prism, with each SLM modulating the light and directing it back to the associated TIR prism. As directed, the light is then transmitted by the prisms to lenses for projection onto a screen. See Poradish, col. 3, ll. 6-39. In essence, therefore, the Poradish patent contemplates use of dual DMDs present in parallel paths existing from separate light sources to a screen.

While the techniques of the Venkateswar and Poradish patents arguably might enhance the resolution of an image produced by a digital projector, alone either is unlikely to provide resolution consistent with that of large-format film. Enhanced resolution of images produced by digital projection systems thus remains a significant issue for those engaged in development of commercial projection equipment. Absent further advancement in this area, viewing of electronically projected images may remain less satisfying to public audiences.

SUMMARY OF THE INVENTION

The present invention seeks to provide such advancements by addressing deficiencies of, typically (but not necessarily exclusively) electronic, SLM-employing

projectors. It further does so in a more comprehensive manner than heretofore considered, attempting to create equipment and techniques capable of providing images of sufficient overall quality that they may be used in venues instead of, or in addition to, traditional large-format film projectors without disturbing audience perception that the viewed images are of high quality. As noted above, this perception is a significant aspect of modern-day viewing experiences, at times helping determine overall success among the public of particular motion pictures.

Embodiments of the present invention utilize not only superimposition, but also tiling to effect improvements to resolution of digitally projected images. "Tiling" describes the concept of joining two or more groups of images (or "sub-images") edge to edge, with each sub-image containing only a fraction of the total projected image. Because each sub-image conveys only a fraction of the overall image, its resolution will be greater than if the sub-image conveyed the total image itself.

Difficulties exist in, among other things, blending the images depicted at the edges of the tiled sub-images. Because abutting sub-images may result in the presence of seams visible to viewers, adjacent sub-images often are overlapped at their common edges to reduce the visibility of these seams. Mere overlapping of sub-images typically is insufficient, however, as the additive intensity of the images in the regions of overlap in some scenes likewise may be noticeable to audiences. General methods of reducing brightness in these regions typically include adjusting the images either electronically or optically; the latter method usually implemented using an opaque or reflective element placed in the beam of light.

Embodiments of the present invention employ instead a pyramid prism both to tile separate sub-images and to provide the requisite decrease in intensity of the sub-images in their regions of overlap. The sides of the pyramid prism constitute the reflective surfaces that combine separate sub-images together, while the apex of the prism acts as a complementary knife edge which optically provides the fall-off in intensity needed for enhanced blending of the sub-images in their overlapping regions. An additional advantage of using the pyramid prism is that, by moving it forward and backward relative to the optical axis of the projector, fine-tuning of the size of the overlap regions can be achieved. Yet another advantage of the pyramid prism as beam combiner is that it admits use of a single projection lens, thus reducing cost and complexity of the overall system. Finally, to the extent seams exist in the overlap region, the techniques of the present invention tend to position such seams in the center of the projection lens, where aberrations are lowest.

Tiling may be combined with superimposition if the light from complementary, offset SLMs is combined into a single image and directed to one side of the pyramid prism, while the light from additional complementary, offset SLMs is combined into a single image and directed to the other side of the pyramid prism.

In a two SLM system, for example, such a combination may be accomplished by a series of polarizing beam splitters. One SLM is directed first to the transmissive face of a beam splitter, and then to the reflective face of a second beam splitter. The other SLM is first directed to the reflective face of a third beam splitter and then to the transmissive face of the second beam splitter where the images of the two SLMs are combined. This arrangement of polarizing beam splitters overcomes a well known defect of these devices which is that the polarizing action of either the reflection or transmission has a better extinction of the unwanted direction of polarization. By combining a reflection and a transmission for each of the SLMs the extinction that results is the same for each SLM while providing each SLM image with an orthogonal polarization with respect to the other.

If desired the resulting superimposed SLM images may be viewed with glasses with two polarizing lenses with orthogonal polarization. This causes the image of one SLM to be seen by one eye and the image of the other SLM to be seen by the other eye. In this case two images may be stereo image pairs, providing for stereoscopic, or "3D," projection, a result desirable or advantageous for some pictures. In this case the benefits of superimposition are lost, but the projector is now flexibly used for 2D projection with enhanced resolution from superimposition, or used for 3D projection with lower resolution but without additional equipment except for the polarizing glasses worn by the viewer.

The combination of superimposition and tiling of sub-images provides high spatial resolution without significantly increasing system size, cost, or complexity. A system using four SLMs, each of 1280 x 1024 pixels, for example, arranges as two tiles, each composed of two superimposed SLMs. This arrangement results in a final screen resolution of approximately 1800 (vertical) x 2750 (horizontal) pixels through one projection lens, alone presenting a substantial increase in resolution.

The present invention nevertheless contemplates further enhancement of the quality of projected images. Selected embodiments of the invention may use additional SLMs as pre-modulators to improve the contrast, or dynamic range, of the system. Ideally, two or more SLMs would be arranged so that there exists precise one-to-one correspondence of their pixels. Each SLM could be driven independently but in concert so that their dynamic range capabilities would combine to extend the resulting dynamic range. Alternatively, a

coarser (i.e. with less resolution) SLM may be used as the pre-modulator to enhance the dynamic range of a group of pixels of the associated downstream SLM.

Some preferred embodiments of the invention employ a single-pixel pre-modulator (typically an SLM) adapted to improve the dynamic range of the entire downstream SLM. In operation, the pre-modulator would function to block light from the downstream SLM to darken its entire image and enhance the black levels of selected scenes. The downstream SLM would retain its full dynamic range capability, but would have as its input new illumination levels when appropriate or desired. For scenes that are bright, the pre-modulator need not be activated; in which event normal brightness levels would be maintained. The pre-modulator thus may be used to adapt the projector to scene brightnesses, matching generally how the human visual system functions.

Yet additional features of the present invention include luminance compensation for selectively increasing the illumination levels provided by the downstream SLMs when, for example, further overall scene contrast is desired. Compensation algorithms may particularly be useful when single-pixel pre-modulators are used, as the global pre-modulation they provide may occasionally diminish too much the input to the downstream SLMs. Finally, improved scene contrast additionally may occur through use of one or more masks for the superimposed, tiled images. These masks may be used effectively to block unwanted glare produced around the edges of the SLMs. In particular, when tiling of multiple SLMs is to occur, a secondary "shading" mask may be employed in a plane axially defocussed from a relayed image for improved results.

It thus is an object of the present invention to provide methods and equipment for enhancing characteristics (including but not limited to resolution, contrast, and dynamic range) of projected images.

It is another object of the present invention to provide methods and equipment for performing such enhancement more comprehensively than heretofore considered, employing techniques including (but again not limited to) either or both of superimposing and tiling sub-images.

It is a further object of the present invention to provide methods and equipment for reducing visible seaming of tiled images, some methods beneficially utilizing both the reflective surfaces and the apex of a pyramid prism.

It also is an object of the present invention to provide methods and equipment for polarizing light from offset light sources and combining the polarized images, which may then be used (if desired), for stereoscopic projection.

It is an additional object of the present invention to provide techniques and equipment for projection in which one or more pre-modulators are employed to improve contrast, or dynamic range, of projected images.

It is yet another object of the present invention to provide techniques and equipment in which one-pixel pre-modulators are utilized, with such equipment optionally including compensation algorithms for correctional purposes.

It is, moreover, an object of the present invention to provide one or more optical masks to reduce glare around edges of and otherwise improve contrast of projected images.

Other objects, features, and advantages of the present invention will be apparent to those skilled in the relevant art with reference to the remainder of the text and drawings of this application.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a schematicized depiction of a first sub-image output from a first SLM.

FIG. 1B is a schematicized depiction of a second sub-image output from a second SLM.

FIG. 1C is a schematicized depiction of the second sub-image superimposed on the first sub-image to form a first composite image.

FIG. 1D is a schematicized depiction of the first composite image tiled with a second, similarly created composite image to produce an overall projected image using techniques of the present invention.

FIG. 2 is a schematicized diagram of components of an exemplary system of the present invention, which may be used to produce the image of FIG. 1D.

FIG. 3 is a schematicized diagram showing a pre-modulator, which may be employed as part of the present invention.

FIG. 4 is a schematicized diagram of a simplified optical relay system showing exemplary placement of an edge mask.

FIG. 5 is a schematicized diagram of the system of FIG. 4 showing, as well, exemplary placement of a secondary shading mask.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 2 illustrates components that may be utilized as part of or in connection with an exemplary projector 100 of the present invention. As shown in FIG. 2, projector 100 may include first and second SLM sets 1 (comprising 1a and 1b) and 2 (comprising 2a and 2b), respectively, each of which may (but need not) comprise one or more DMDs. Likewise, although four SLMs are depicted (as elements 1a, 1b, 2a, and 2b) in FIG. 2, fewer or greater numbers may be employed yet remain consistent with various of the techniques of the present invention.

Also depicted in FIG. 2 are three polarizing beam splitters 6, 7 and 8. The image of SLM 1a via relay lens 4 is transmitted through polarizing beam splitter 8 and reflected by beam splitter 7 through second relay lens 9 to mirrored pyramid prism 10. At the same time the image of SLM 1b via relay lens 5 is reflected by polarizing beam splitter 6 and transmitted through polarizing beam splitter 7 through second relay lens 9 to mirrored pyramid prism 10. The two SLM images are combined in polarizing beam splitter 7, with the one having an orthogonal polarization with respect to the other. In each case polarizing beam splitters 6 and 8 provide a "clean up" function to ensure that extinction of the unwanted polarizing component is achieved for both SLM images which is a requirement when the system is used for 3D stereoscopic image projection.

The SLMs of each of sets 1 and 2 typically are complementary, with the optical output of one spatially offset (preferably) one-half pixel both horizontally and vertically with respect to the other. Thus, as each splitter 7 combines the beams of the SLMs of its associated set 1 or 2, the sub-image of SLM 1a effectively is superimposed on that provided by SLM 1b (or vice-versa), and the sub-image of SLM 2a is superimposed on the sub-image produced by SLM 2b (or vice-versa). This relationship for a set 1 or 2 is depicted generally in FIG. 1C, which illustrates the optical output of, for example, SLM 1a (see FIG. 1B) superimposed on that (see FIG. 1A) of SLM 1b. As clearly discernable from FIG. 1C, such superimposition indeed may enhance the resolution of (or brighten or increase dynamic range of) the composite image by providing additional image information in the pixel interstices of the images produced by either SLM of set 1 or 2.

Once again, conventional relay optics 9 may be used to convey the combined (superimposed) beams to a tiling mechanism, shown in FIG. 2 as pyramid prism 10. Each combined beam impinges on a reflective side of prism 10 in a manner permitting the apex of prism 10 to dampen the intensity of the illumination of the region of their intended overlap. This permits prism 10 to combine the composite beams to produce a tiled image 12 having

well-blended intensity in the region of their overlap. Such image 12 may then be passed to projection lens 13 for projection onto a screen or other suitable surface or object. If desired, an edge mask 11 may be interposed between prism 10 and lens 13 to reduce edge glare or other undesirable characteristics of tiled image 12 before it is projected. Although those skilled in the art undoubtedly appreciate advantages available through use of the surfaces and apexes of pyramid prism 10, different tiling mechanisms may be used instead without undermining other novel aspects of the present invention.

Relay optics 9 may also function to equalize magnification of the optical signals of the two channels (one emanating from SLM set 1 and the other from SLM set 2) of projector 100 before the signals are projected through lens 13. Such function is especially important in certain embodiments of projector 100, which may omit pyramid prism 10 in favor of other edge-blending mechanisms (placed either before or after lens 13 in the optical path). One alternative to prism 10 is a pair of mirrors, one for each optical channel of the projector 100. In effect, the two optical paths are directed to separate mirrors (rather than prism 11) and thence through separate lenses (instead of the single lens 13 shown in FIG. 2) for projection onto a screen. In these embodiments, the tiled image is formed at the screen rather than within projector 100.

FIG. 3 illustrates pre-modulator 24 that may be used as part of the present invention. Light 22 from lamp 21 and reflector 20 is directed by cold mirror 23 to pre-modulator 24. Noted earlier is that pre-modulator 24 can be an SLM, preferably (although not necessarily) a single-pixel device in some embodiments, utilized to improve the dynamic range of downstream SLMs. Light modulated by pre-modulator 24 may than travel through integrating bar 25 and through illumination relay 26 to SLM 27. Such SLM 27 corresponds to either SLMs 1a and 1b or SLMs 2a and 2b of FIG. 2.

FIG. 4 details exemplary placement of an edge mask, denominated 205, in a simplified illustration of an optical relay system 200. Conceptually, system 200 may be used to create an intermediate image of an SLM (or other light source) in space beyond a prism 202. Creating the image in this location would allow the use of a rectangular mask (as mask 205) to select only the rectangular active area of the SLM to pass to subsequent optical systems. This would effectively eliminate the areas of the SLM illustrated by scatter and beam overfill. The overall effect would be to enhance system contrast and control the edge illumination enabling successful tiling of separate SLM images.

As shown in FIG. 4, SLM assembly 201 is attached to prism 202 through which light is directed toward relay lens 203. An image of the SLM assembly is located at

numeral 204. Edge mask 205 is located at the plane of image 204 and functions to eliminate edge glare around the whole of the SLM.

Additional masks 205 typically cannot be introduced in the image plane, as they may clip the SLM image and reduce the resulting picture size. However, in parallel planes displaced from the image plane, it is possible to introduce a mask to affect only the illumination cones rather than the image size. Doing so permit modification of the image illumination along the "overlap" side so as to reduce the overlap intensity.

In FIG. 5, a shading mask 206 has been introduced between relay lens 203 and SLM image 204. Shading mask 206 will clip the illumination cone but should not affect image size. Rather, it will affect the illumination distribution at the end of the image without affecting the distribution in other parts of the image. By positioning shading mask 206 at a particular perpendicular distance from the SLM image plane and optical axis, it is possible to create a defined decrease in intensity at the end of the SLM image.

The intensity variation can also be matched spatially with the intended overlap dimension of two adjacent images. A second adjacent image with an identical intensity fall off over the opposite overlap dimension can also be creased. If the two images are then overlapped by the defined overlap dimension, the intensity should remain constant over the overlap region.

Because the foregoing is provided for purposes of illustrating, explaining, and describing embodiments of the present invention, further modifications and adaptations to these embodiments will be apparent to those skilled in the art and may be made without departing from the scope or spirit of the invention. For example, as noted above, the position of prism 10 relative to lens 13 may be mobile, thereby permitting further refinement of the size of the region of overlap of the beams forming tiled image 12. Pre-modulation, compensation algorithms, and image coding additionally may occur consistent with the invention, and the systems and numbers of components described herein may be scaled as appropriate to effect desired results. Yet additionally, ferroelectric devices, liquid-crystal displays (LCD), or other light sources or valves may be employed as necessary or desired. Finally, in some cases, only green or luminance information might be superimposed.

What is claimed is:

1. An optical projection system comprising:
   a. a plurality of light sources producing a plurality of images;
   b. means for superimposing at least two of the images; and
   c. means for tiling at least two of the images.

2. An optical projection system according to claim 1 in which the tiling means comprises means for providing enhanced blending in overlapped regions of the tiled images.

3. An optical projection system according to claim 2 in which the tiling means comprises a pyramid prism.

4. An optical projection system according to claim 3 in which the pyramid prism comprises a plurality of sides and an apex, the plurality of sides functioning to combine images and the apex functioning to decrease intensity of illumination to provide the enhanced blending in the overlapped regions.

5. An optical projection system according to claim 4 further comprising a projection lens for projecting superimposed, tiled images.

6. An optical projection system according to claim 1 in which each of the plurality of light sources comprises a DMD.

7. An optical projection system according to claim 5 in which the projection lens defines an optical axis and in which position of the pyramid prism relative to the optical axis can vary.

8. An optical projection system according to claim 2 further comprising at least one polarizing beam splitter interposed optically between at least one light source and the pyramid prism.

9. An optical projection system according to claim 8 in which the polarizing beam splitter has a reflective and a transmissive face and is interposed optically between the

pyramid prism and two light sources, images from one of the two light sources being directed to the reflective face and images from the other of the two light sources being directed to the transmissive face.

10. An optical projection system according to claim 1 further comprising a pre-modulator.

11. An optical projection system according to claim 5 further comprising an edge mask interposed optically between the pyramid prism and the projection lens.

12. An optical projection system according to claim 8 further comprising a combining polarizing beam splitter and an additional polarizing beam splitter interposed optically between at least one light source and the combining polarizing beam splitter.

13. An optical projection system according to claim 9 further comprising a system of relay lenses that act to permit adjustment of the magnification of the images from each of the light sources.

14. An optical projection system according to claim 1 in which the tiling means comprises a plurality of mirrors, further comprising a plurality of projection lenses associated therewith.

15. A method of projecting a plurality of images, the method comprising:
   a. creating the plurality of images;
   b. superimposing at least two of the images; and
   c. tiling at least two of the images.

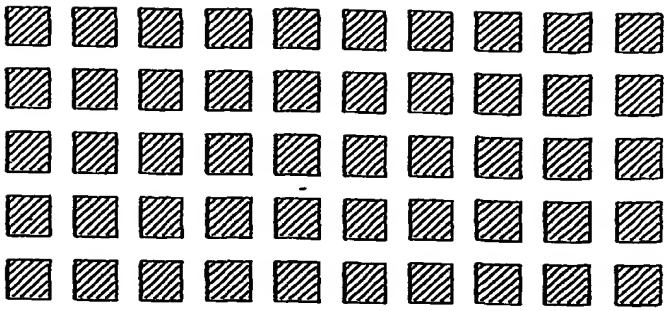
16. An optical system comprising:
   a. a light source;
   b. a relay lens;
   c. a prism interposed optically between the light source and the relay lens; and
   d. an edge mask positioned optically after the relay lens.

17. An optical system according to claim 16 in which the relay lens locates an image at a particular location and in which the edge mask is positioned at the plane of the image.

18. An optical system according to claim 17 further comprising a shading mask interposed optically between the relay lens and the image location.

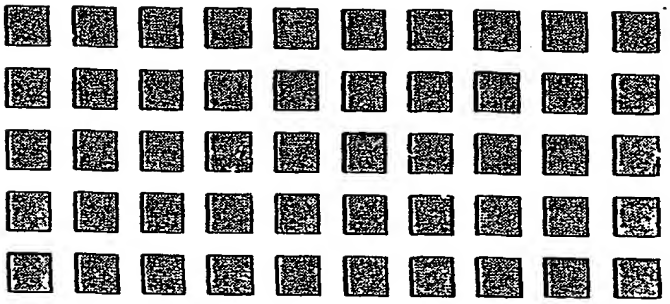
19. An optical system according to claim 5 further comprising a second plurality of light sources producing a second plurality of images and a second projection lens for projecting the second plurality of images or images derived therefrom.

FIG. 1A



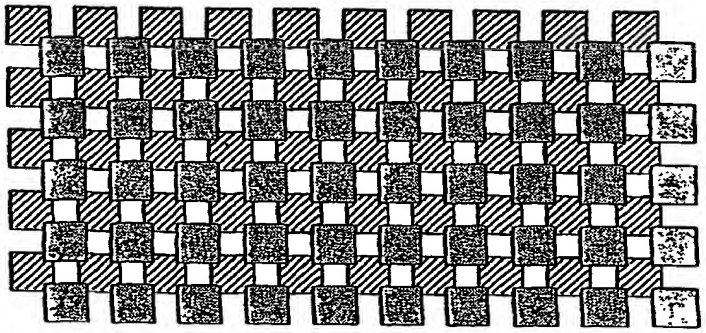
DMD 1

FIG. 1B



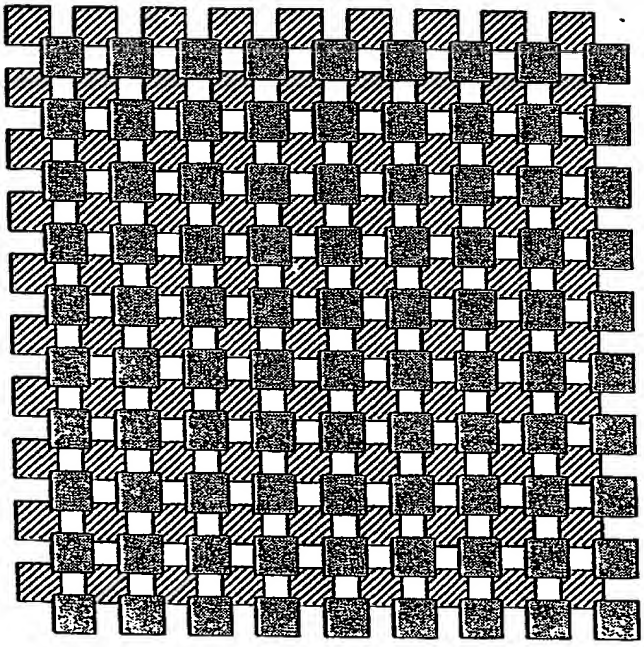
DMD 2

FIG. 1C



DMD 2 superimposed on DMD 1

FIG. 1D



2 pairs of DMD 2 superimposed on DMD 1 tiled together

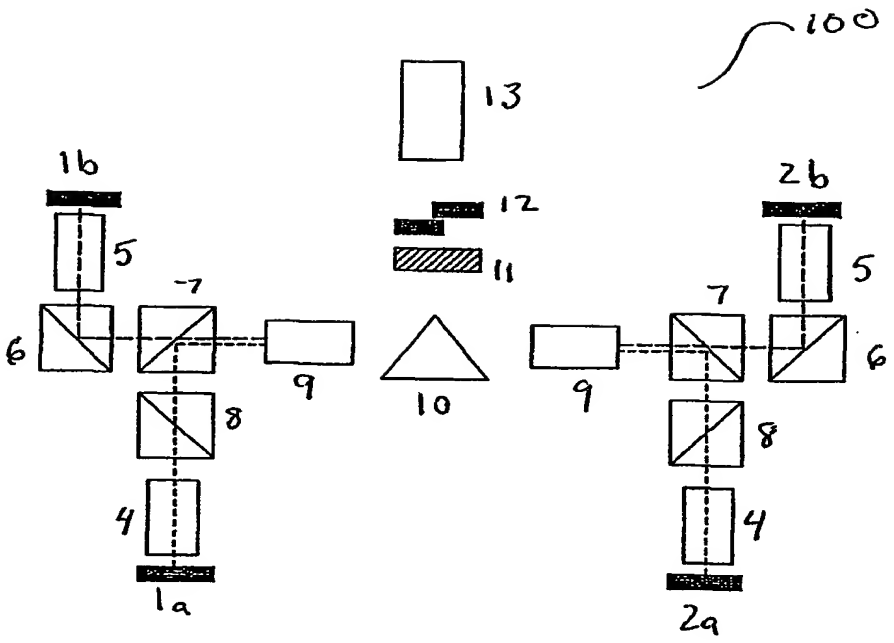


Figure 2

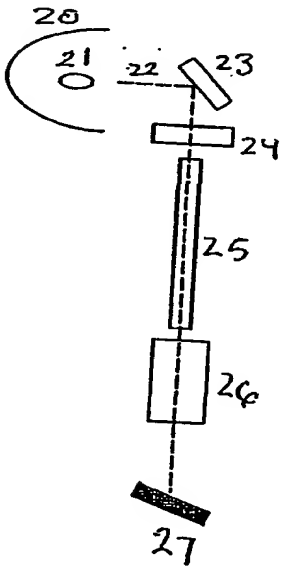


Figure 3

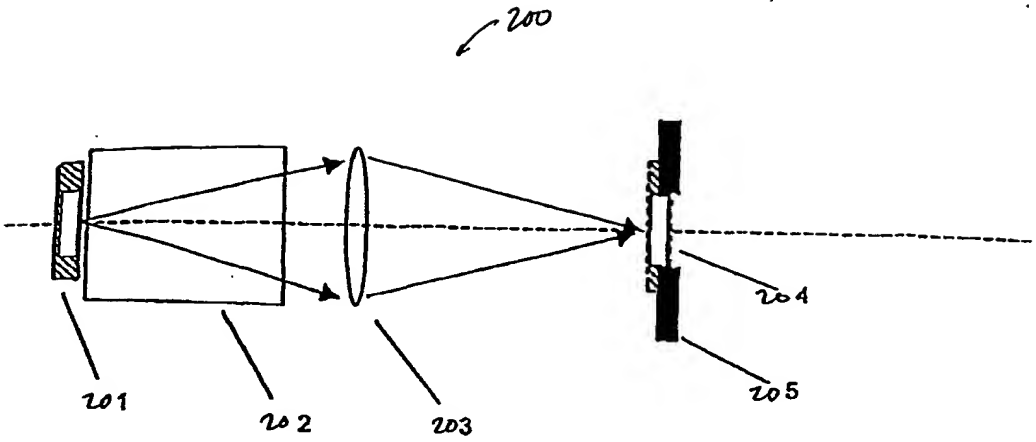
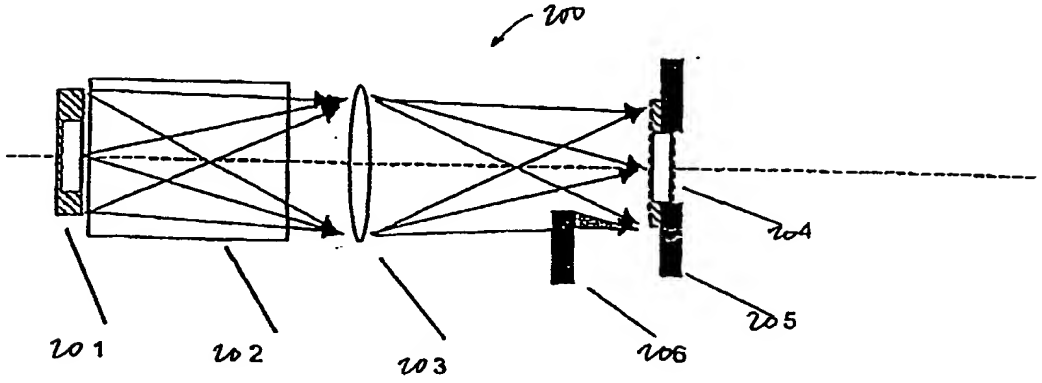


Figure 4



Edge illumination cones lose a major percentage of their light

Figure 5